Biology

Mitosis and Meiosis

Assis. Prof. Dr. Labeed Al - Saad

Objectives

- Understand the basic concepts and principles of mitosis and meiosis.
- Identify the stages and mechanisms involved in mitosis and meiosis.
- Compare and contrast the differences and similarities between mitosis and meiosis.
- Understand the importance of mitosis and meiosis in the growth, development, and reproduction of living organisms.

Introduction to Mitosis and Meiosis

- Mitosis: is a process of cell division in which a single eukaryotic cell divides into two genetically identical daughter cells, each with the same number of chromosomes as the parent cell. This division is crucial for growth, development, tissue repair, and maintenance of the organism. Mitosis consists of several stages: prophase, metaphase, anaphase, and telophase. The end result is the distribution of replicated chromosomes into two separate nuclei, ensuring the genetic continuity of the cells.

Introduction to Mitosis and Meiosis

- Meiosis: is a specialized type of cell division that occurs in sexually reproducing organisms. Unlike mitosis, meiosis involves two sequential divisions, resulting in the production of four non-identical haploid cells (gametes), each with half the number of chromosomes as the original diploid cell. Meiosis is essential for generating genetic diversity in offspring, as it shuffles and redistributes genetic material through processes like crossing over and independent assortment. This contributes to the variability observed in sexually reproducing organisms.

Importance of mitosis in living organisms

Importance of Mitosis:

- Growth and Development: Mitosis is crucial for the growth and development of multicellular organisms. It allows for the increase in cell number, leading to the formation of tissues, organs, and ultimately, a fully developed organism.
- Tissue Repair and Maintenance: Injuries, wear and tear, or cell loss are common occurrences in organisms. Mitosis plays a vital role in the repair and maintenance of tissues by replacing damaged or dead cells with new, identical ones.

Importance of mitosis in living organisms

Importance of Mitosis:

- Asexual Reproduction: In some single-celled organisms and certain multicellular organisms, mitosis is the primary means of reproduction. It results in the production of genetically identical offspring, contributing to population expansion.

- Genetic Stability: Mitosis ensures that the genetic material is faithfully replicated and distributed to daughter cells, maintaining genetic stability across generations of somatic cells.

Importance of meiosis in living organisms

Importance of Meiosis:

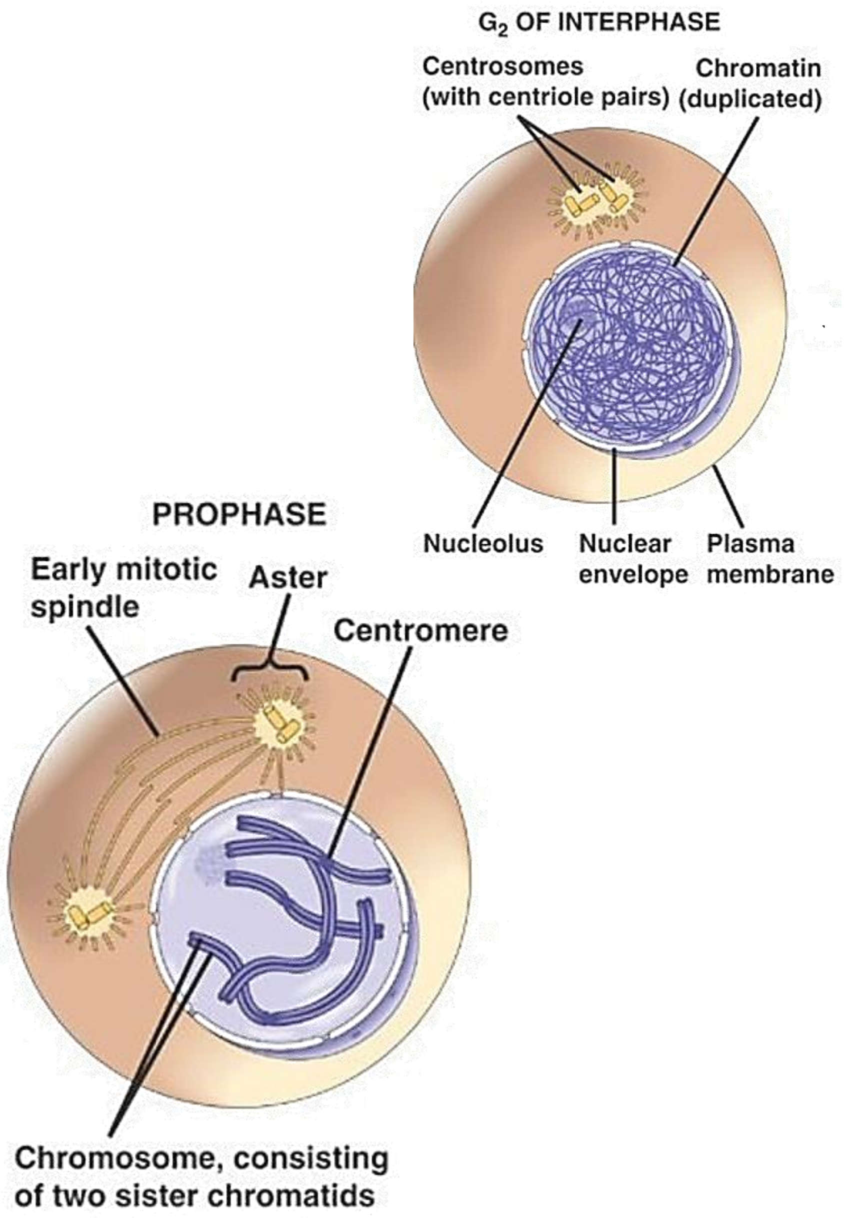
- Prevention of Chromosome Doubling: Without meiosis, each generation in sexually reproducing organisms would result in a doubling of the chromosome number. Meiosis ensures that the chromosome number remains constant across generations.
- Adaptation and Evolution: The genetic variability introduced by meiosis is a driving force behind adaptation and evolution. It allows for the selection of advantageous traits over time, contributing to the survival and success of populations in changing environments.

In summary, both mitosis and meiosis are fundamental processes in the life cycles of organisms. Mitosis supports growth, development, and maintenance, while meiosis is crucial for genetic diversity, sexual reproduction, and the long-term adaptation and evolution of species.

The Phases of Mitosis

Prophase:

- Chromatin Condensation: The chromatin (a complex of DNA and proteins) in the cell nucleus condenses into visible chromosomes. Each chromosome consists of two sister chromatids held together by a centromere.
- Nuclear Envelope Breakdown: The nuclear envelope begins to break down, allowing the chromosomes to move freely in the cell.

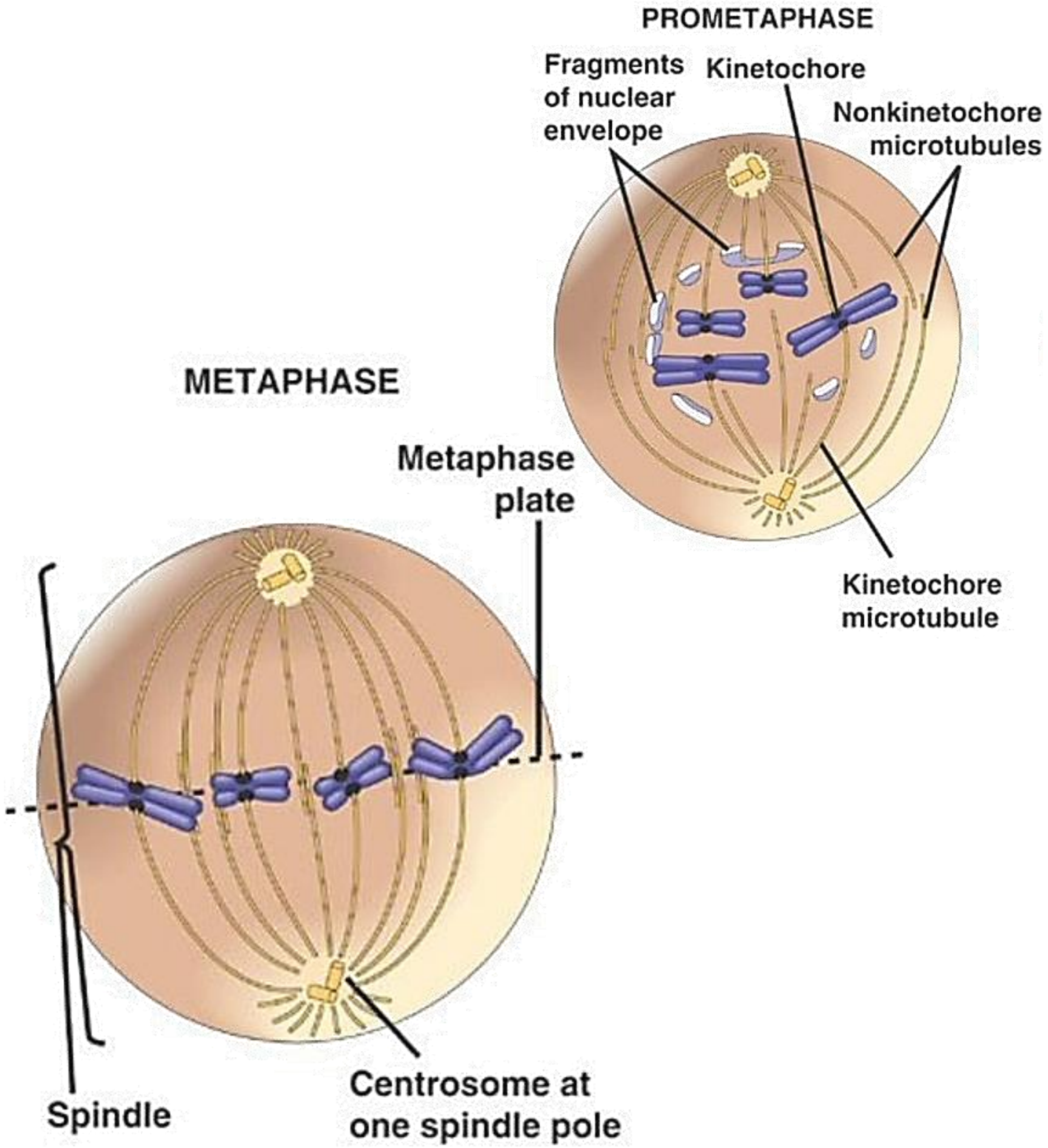


https://owlcation.com/stem/Stages-of-the-Cell-Cycle-Mitosis-Part-2-of-2

The Phases of Mitosis

Metaphase:

- Chromosomal Alignment: The condensed chromosomes align along the metaphase plate, an imaginary plane equidistant between the two poles of the cell. The spindle fibers, microtubules responsible for separating chromosomes, attach to the centromeres of the chromosomes.



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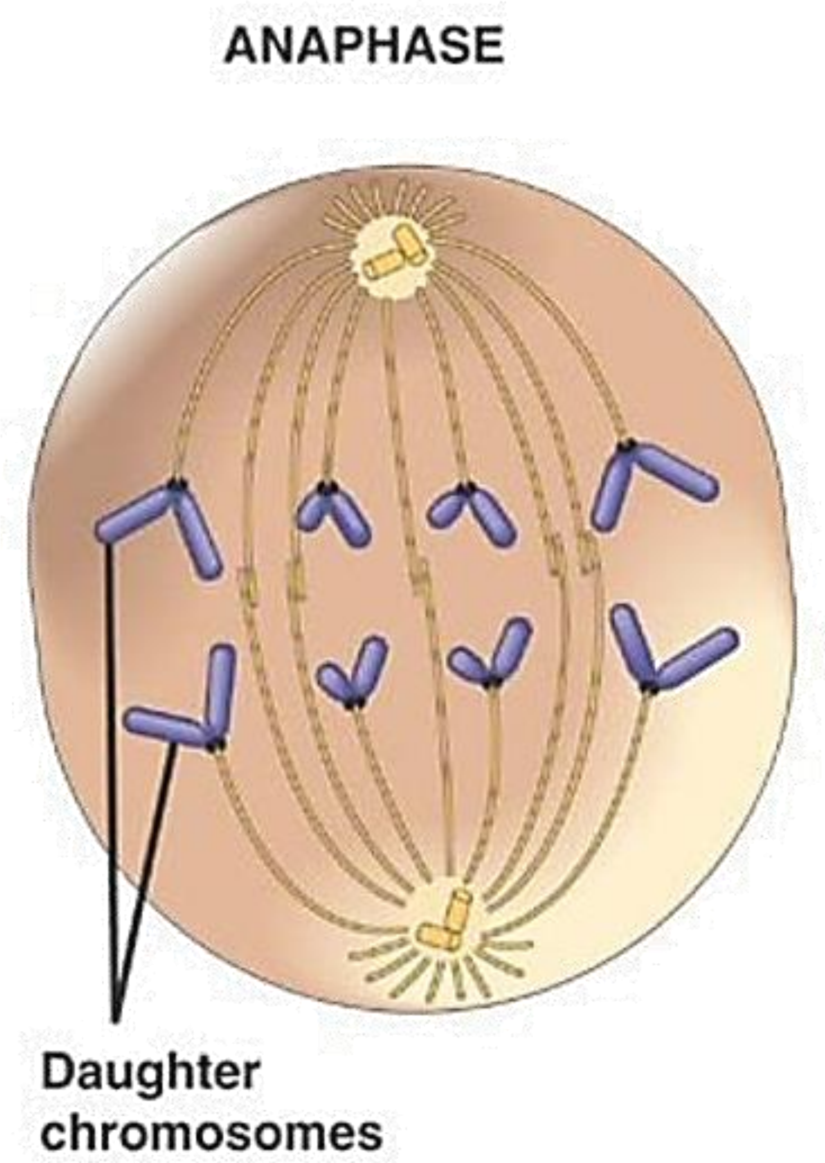
The Phases of Mitosis

Anaphase:

- **Chromatid Separation:** The centromeres split, and the sister chromatids are pulled apart toward opposite poles of the cell by the shortening spindle fibers. This ensures that each daughter cell receives an identical set of chromosomes.



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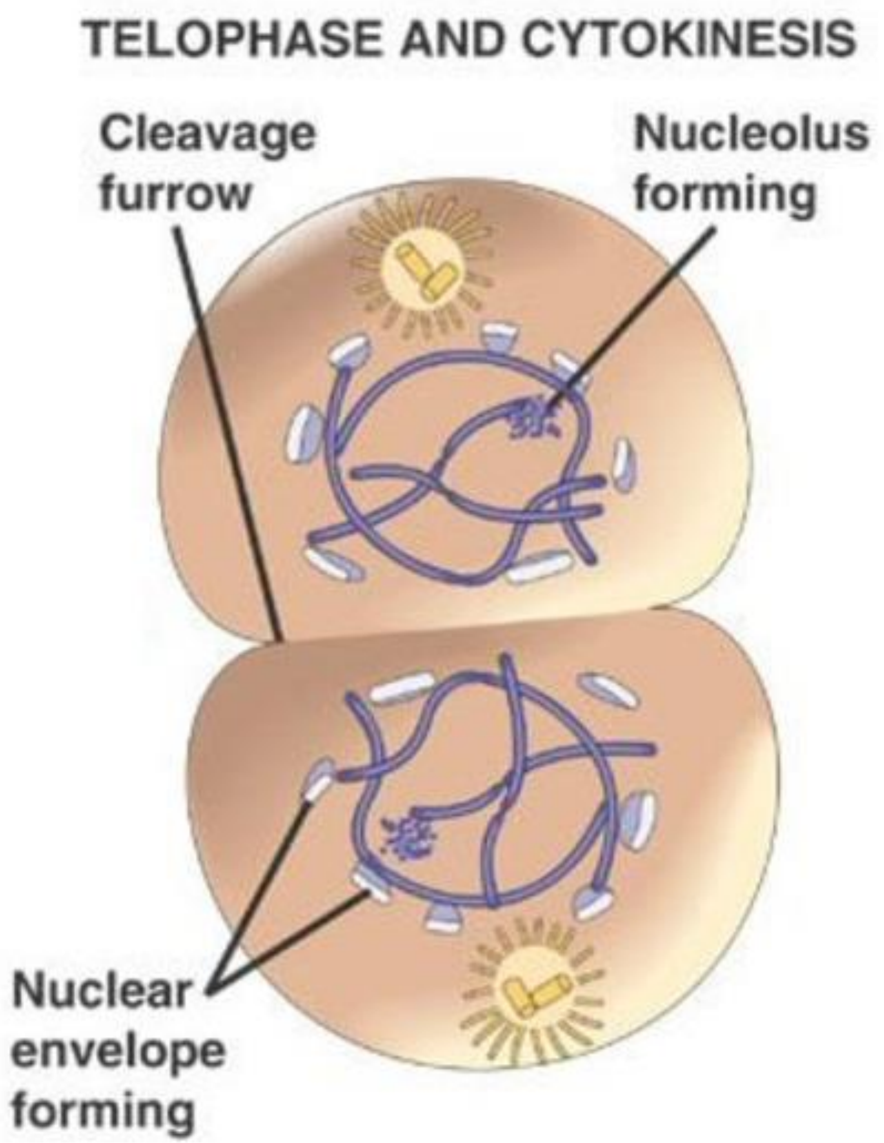
The Phases of Mitosis

Telophase:

- Chromosomes Decondensation: Once the separated chromatids reach the poles, they begin to decondense back into chromatin.
- Nuclear Envelope Reformation: A new nuclear envelope forms around each set of chromosomes at the poles, creating two distinct nuclei.



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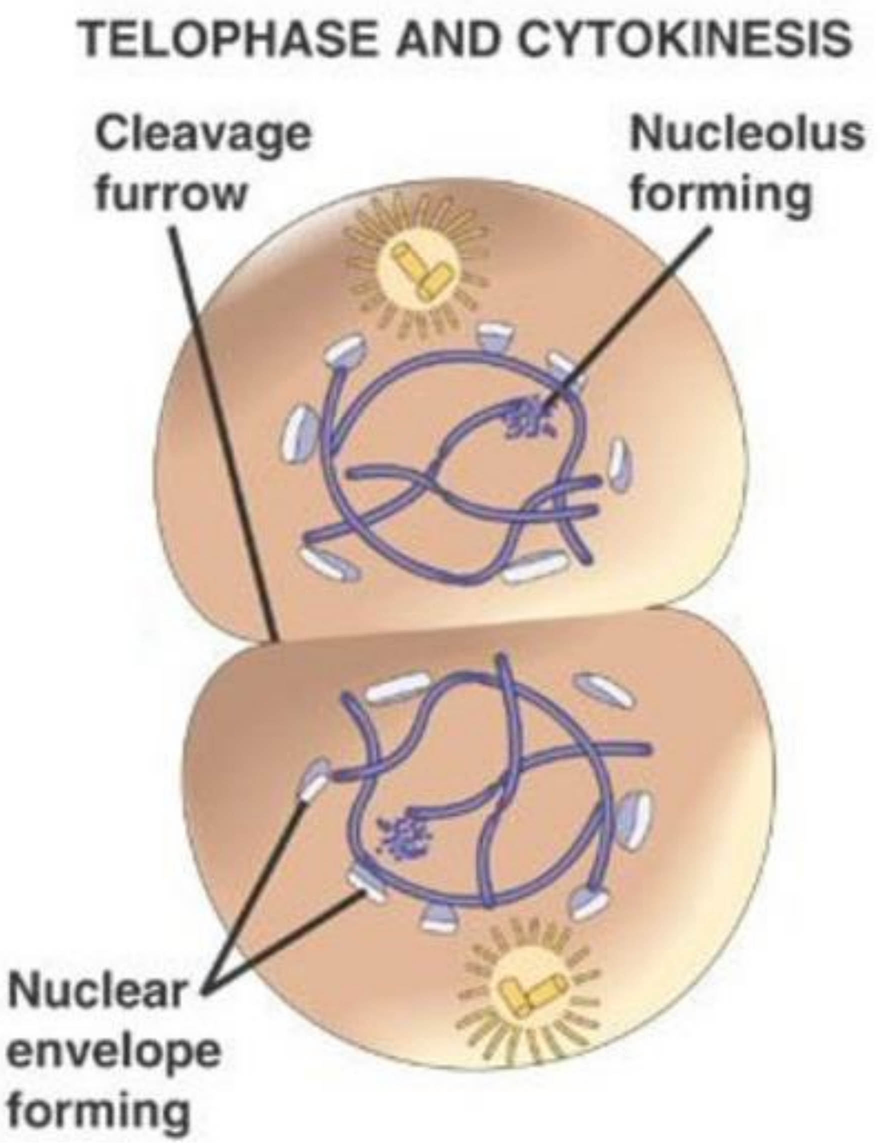
The Phases of Mitosis

Telophase:

- **Cytokinesis:** While mitosis technically ends with the formation of two distinct nuclei, the cell undergoes cytokinesis, the division of the cytoplasm, to produce two separate daughter cells. In animal cells, a cleavage furrow forms, pinching the cell into two, while in plant cells, a cell plate develops in the middle.



Useful video

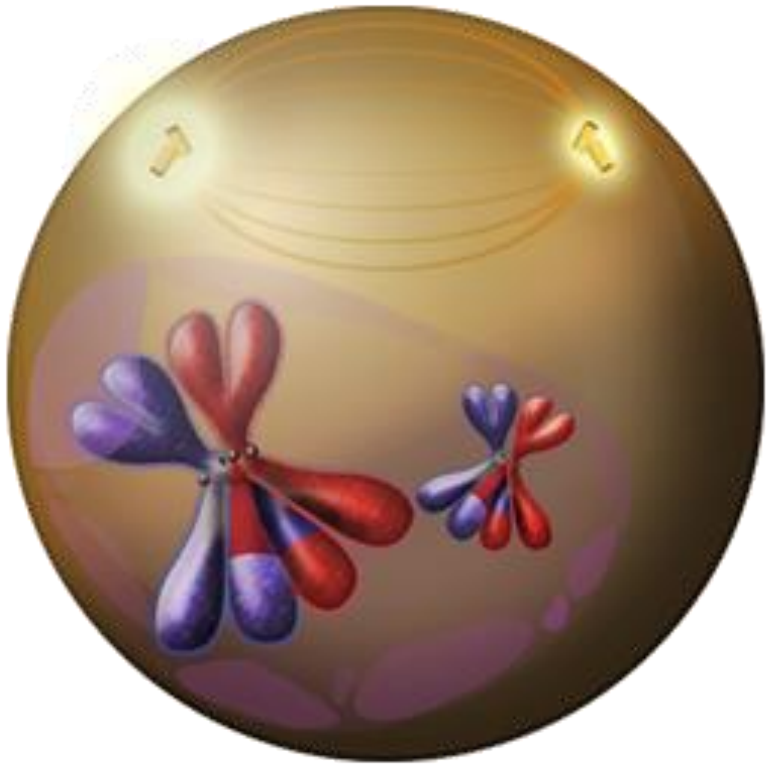
https://www.youtube.com/watch?v=DwAFZb8juMQ&list=PPSV

https://owlcation.com/stem/Stages-of-the-Cell-Cycle-Mitosis-Part-2-of-2

The Phases of Meiosis

Prophase I:

- Chromatin Condensation: Chromatin condenses into visible chromosomes, and homologous chromosomes (chromosomes with similar genetic information) pair up in a process called synapsis.
- Crossing Over: Homologous chromosomes exchange genetic material through a process known as crossing over, contributing to genetic diversity.
- Nuclear Envelope Breakdown: The nuclear envelope starts to break down, allowing the spindle fibers to interact with chromosomes.



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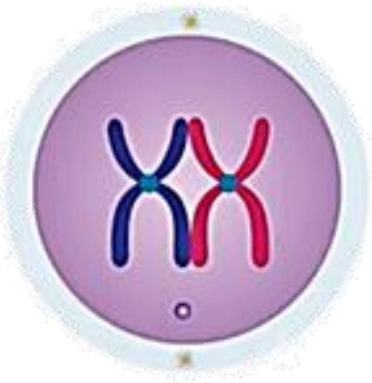
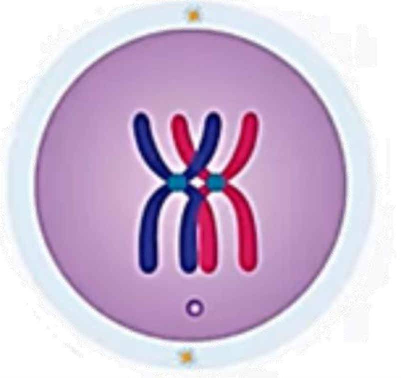
The Prophase I in details

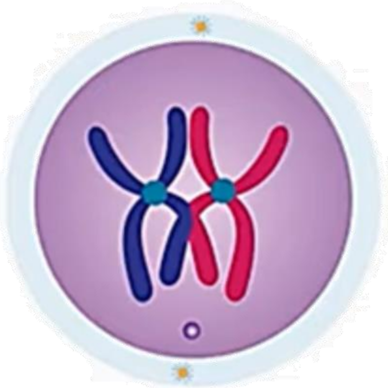
Leptotene
Chromosomes show condensation



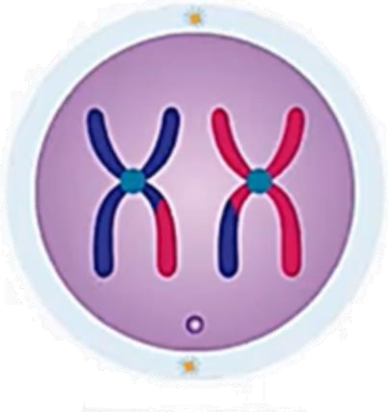
Zygotene
Synapsis: pairing of homologous Chromosomes



Pachytene
Exchange of gene segments between two sister chromatids of homologous chromosomes



Diplotene
Bivalent chromosomes unbutton themselves resulting in separation of the two homologous chromosomes



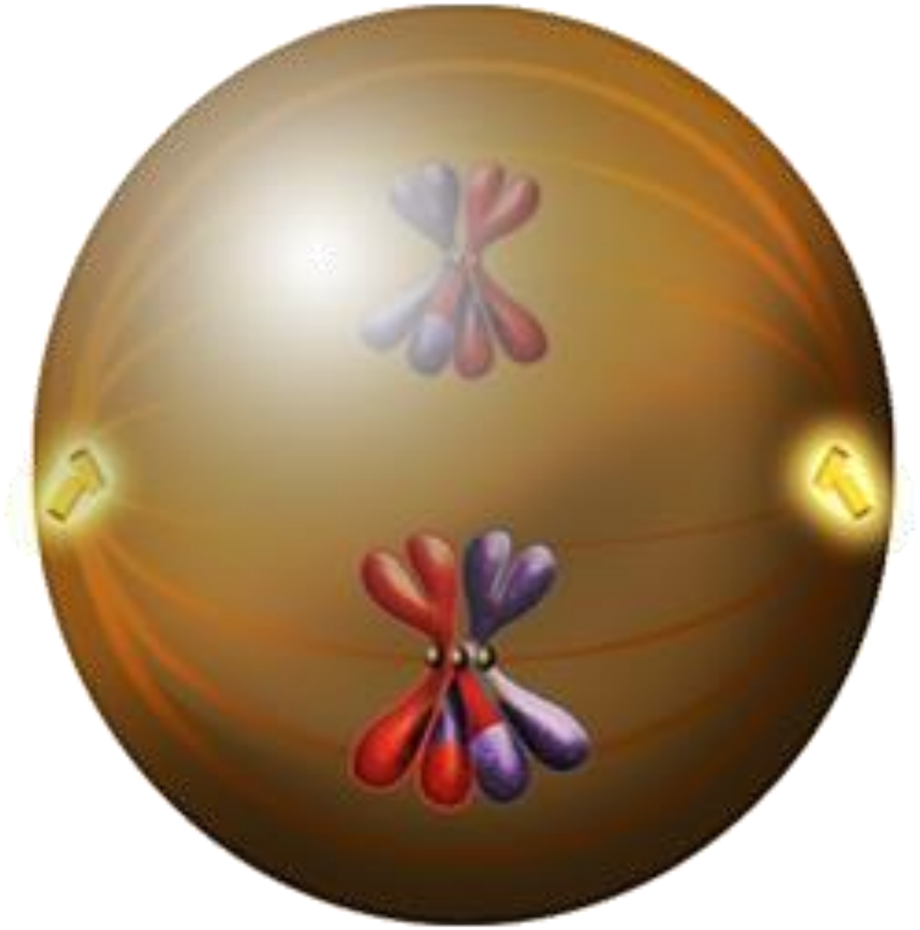
Diakinesis
Homologous chromosomes completely separate from each other and regain their individual identity

https://www.youtube.com/watch?v=_1k1ew-5f3M

The Phases of Meiosis

Metaphase I:

- Homologous Chromosome Alignment: Pairs of homologous chromosomes align along the metaphase plate, with spindle fibers attaching to each chromosome.



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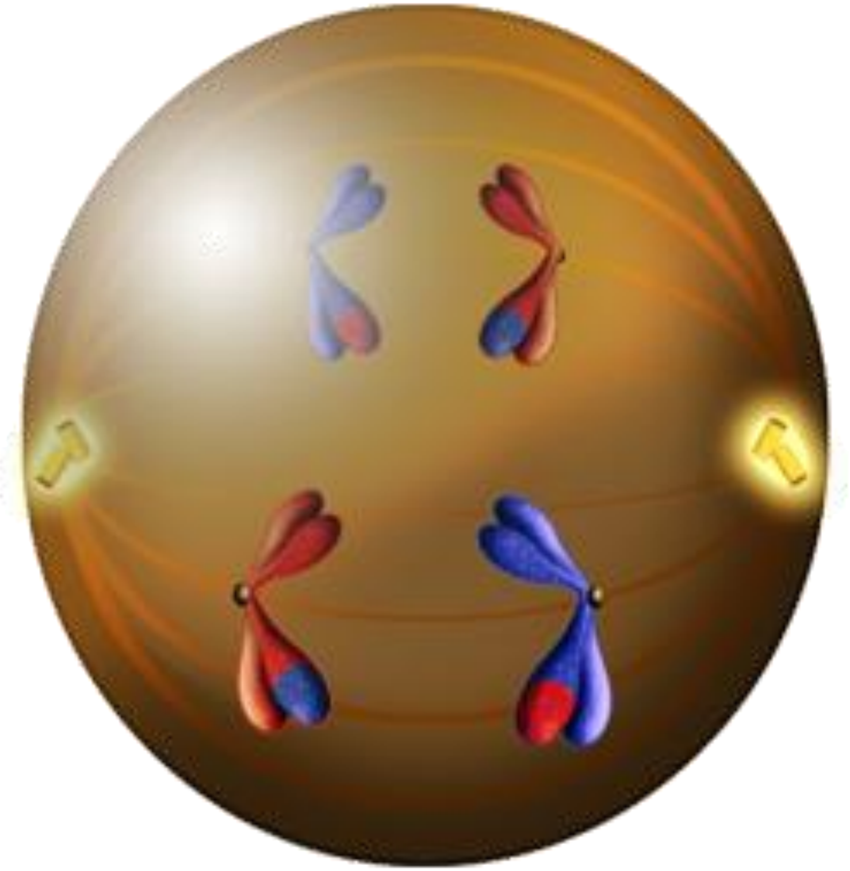
The Phases of Meiosis

Anaphase I:

- Homologous Chromosome Separation: Homologous chromosomes are pulled apart by spindle fibers and move toward opposite poles of the cell. The chromatids remain attached.



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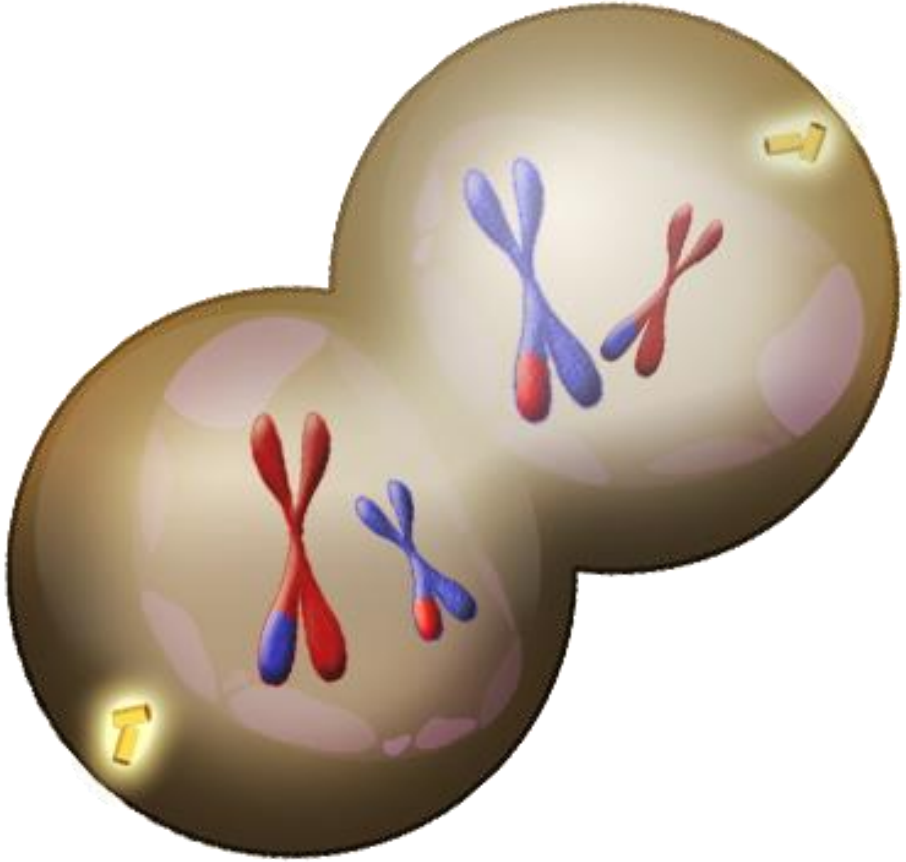
The Phases of Meiosis

Telophase I:

- Chromosomes Reach Poles: The separated chromosomes arrive at the poles, and the nuclear envelope may reform. Each resulting cell is haploid, containing half the chromosome number of the original cell.



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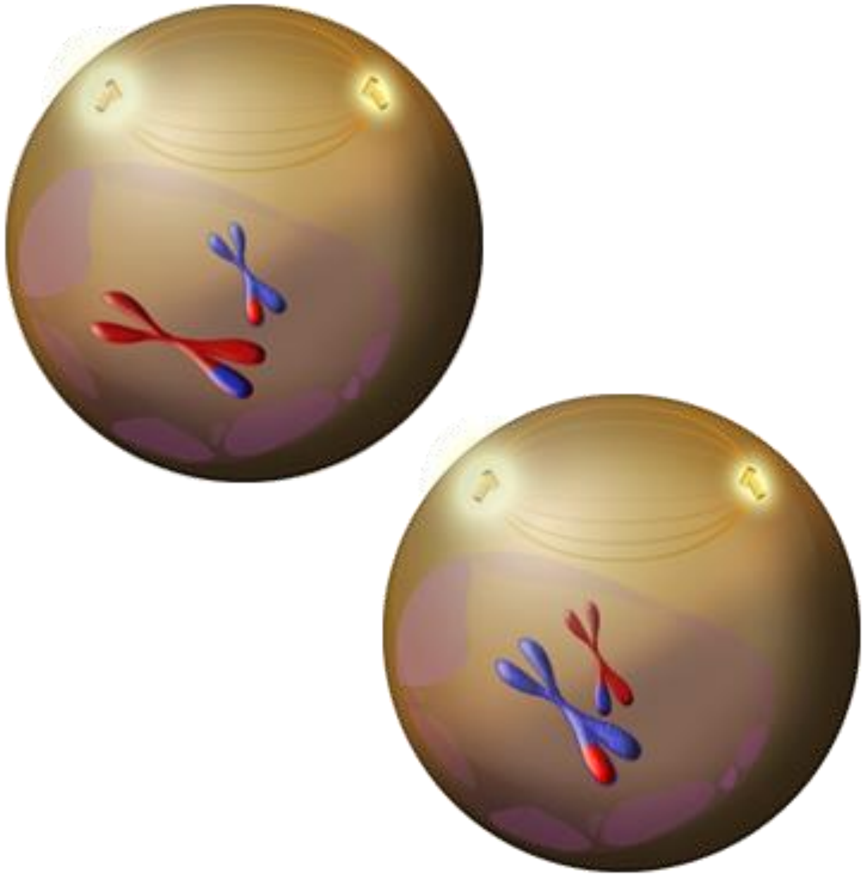
The Phases of Meiosis

Meiosis II:

Meiosis II is similar to mitosis but involves haploid cells.

Prophase II:

- Chromosomes Condense: Chromosomes condense again in each haploid cell, similar to prophase in mitosis.
- Nuclear Envelope Breakdown: The nuclear envelope breaks down.



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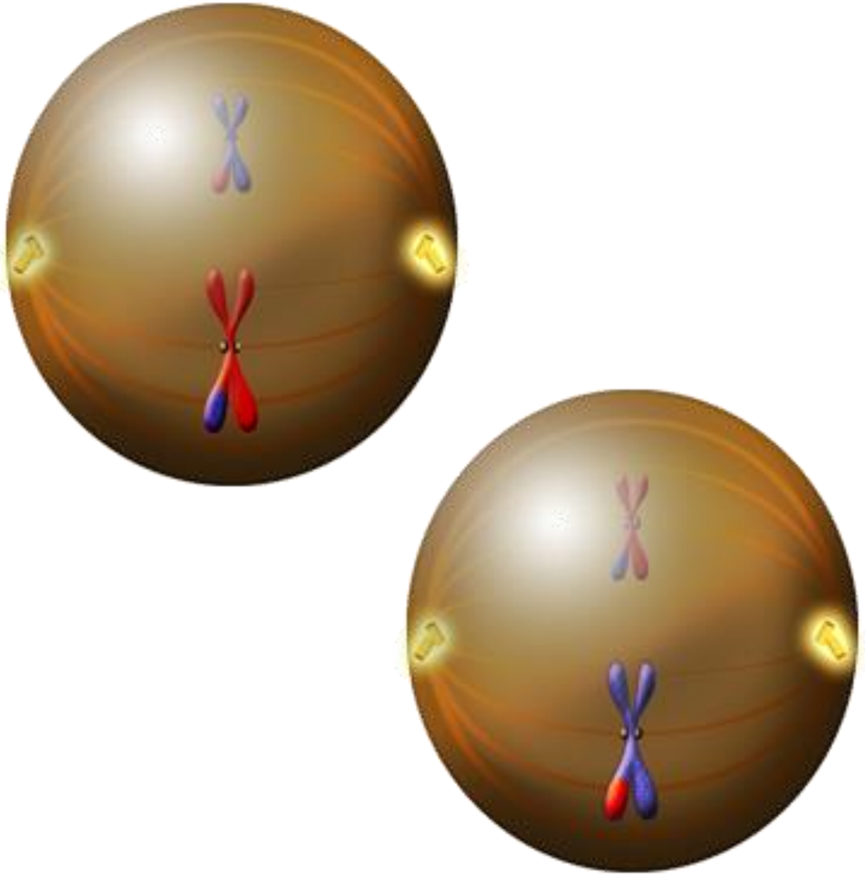
The Phases of Meiosis

Metaphase II:

Chromosomes Align: Chromosomes align along the metaphase plate in each haploid cell.



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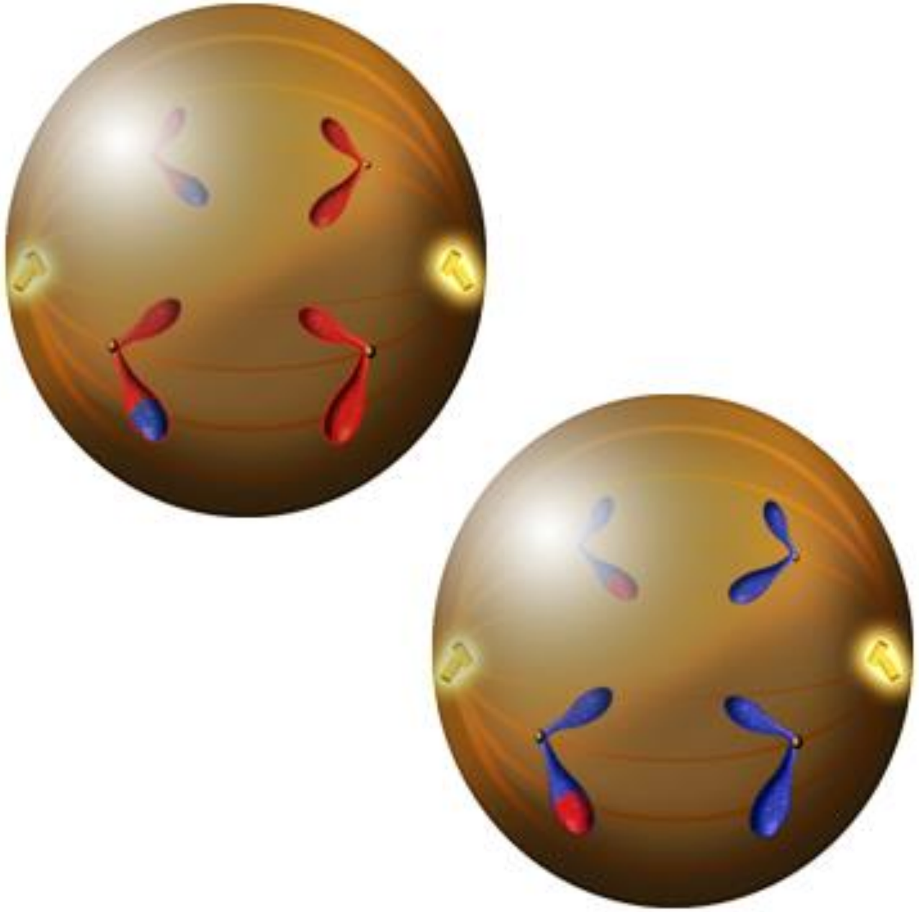
The Phases of Meiosis

Anaphase II:

Sister Chromatid Separation: The sister chromatids of each chromosome are pulled apart by spindle fibers and move toward opposite poles.



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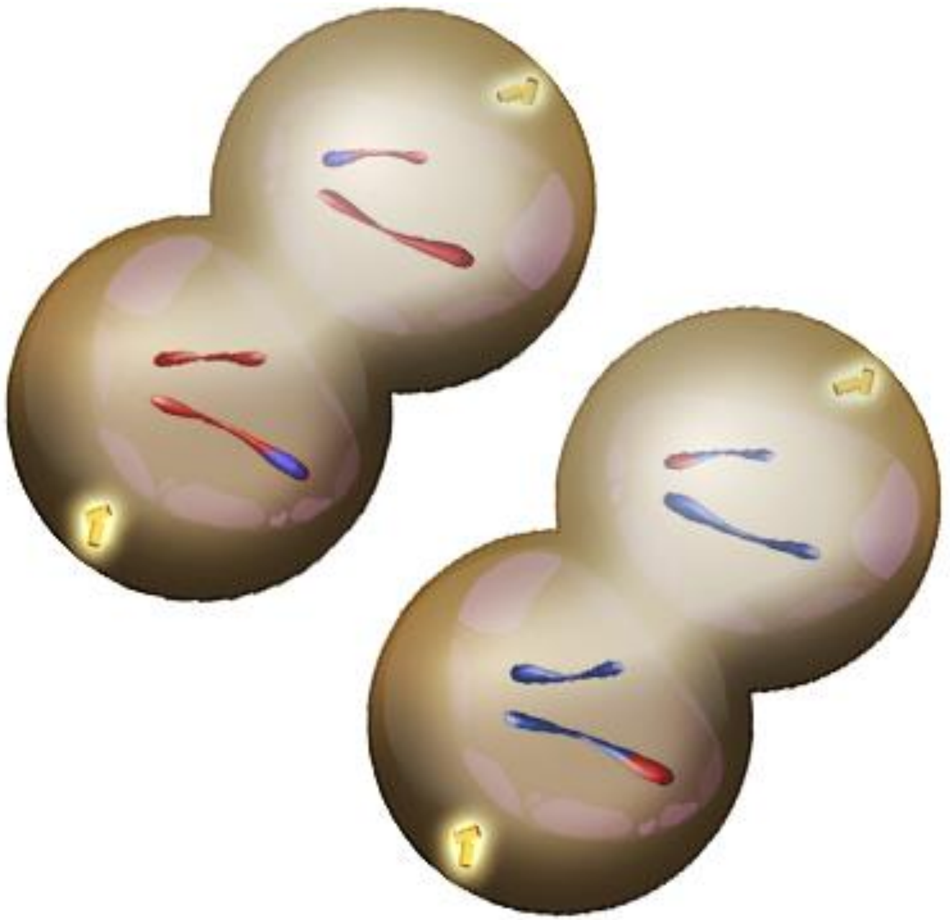
The Phases of Meiosis

Telophase II:

The nuclear membrane reforms (shown by the pale whitish circle) around each set of genetic material. The cells then undergo cytokinesis, forming four daughter cells in total.



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Diagnostic approaches using mitotic and meiotic information

- Karyotyping: This diagnostic approach involves examining the number and structure of chromosomes in a sample of cells. Karyotyping can reveal abnormalities such as aneuploidy (abnormal number of chromosomes) or structural rearrangements.

Useful video

https://www.youtube.com/watch?v=sFxmGfOH_eg

Diagnostic approaches using mitotic and meiotic information

- Fluorescence in situ hybridization (FISH): FISH is a molecular cytogenetic technique that uses fluorescent probes to detect specific DNA sequences on chromosomes. It can be used to identify chromosomal abnormalities or rearrangements.

Useful video

https://www.youtube.com/watch?v=LiRJoTi44TA

Diagnostic approaches using mitotic and meiotic information

- **Array comparative genomic hybridization (aCGH):** This technique involves comparing the DNA from a patient's cells to a reference sample using microarrays. It can detect copy number variations and identify chromosomal imbalances.
- **Next-generation sequencing (NGS):** NGS can be used to analyze the entire genome or specific regions of interest to identify genetic mutations or variations that may be associated with a specific condition.

Diagnostic approaches using mitotic and meiotic information

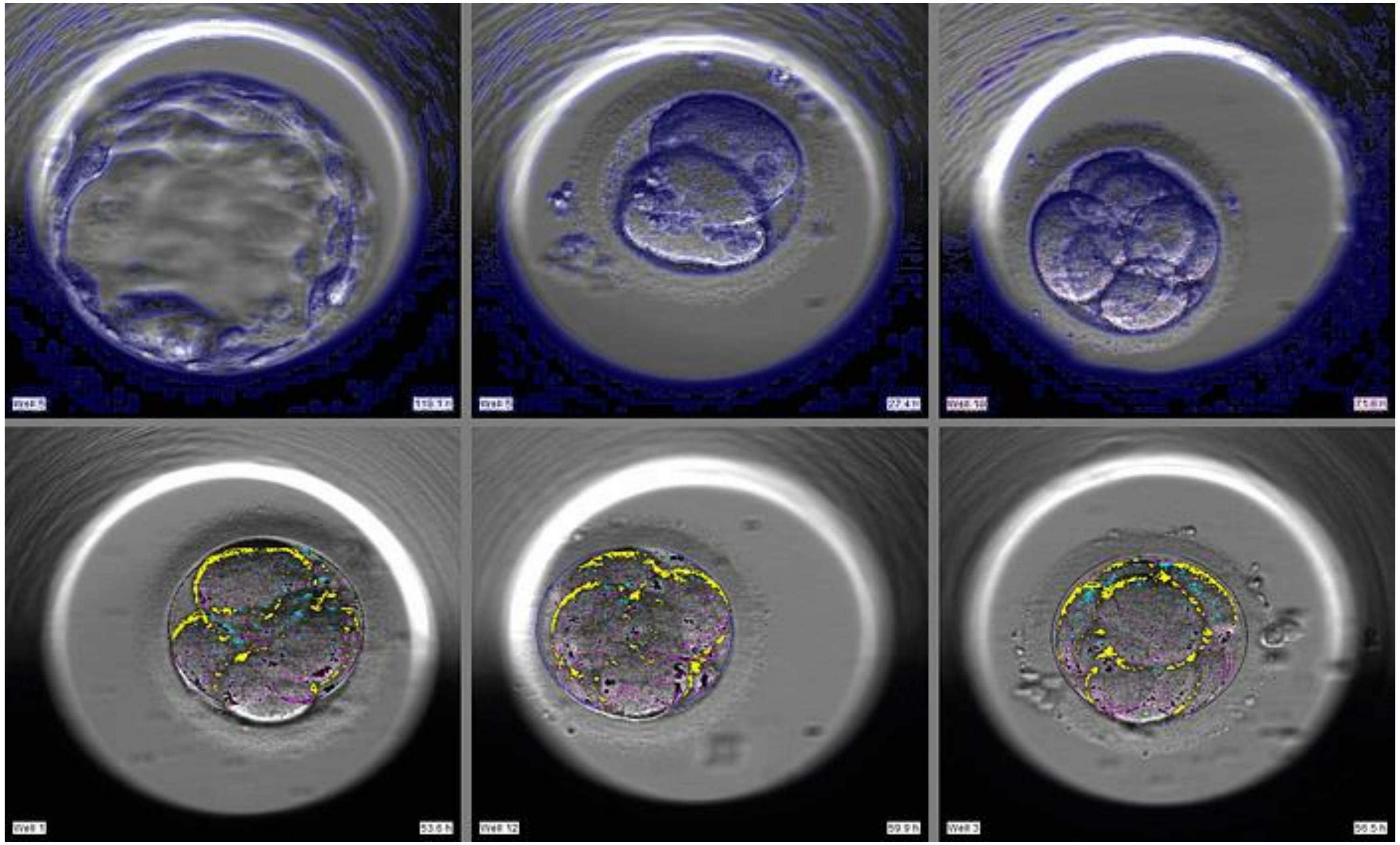
- Meiotic analysis: Meiotic information can be used to assess the risk of genetic disorders in offspring. For example, analyzing the segregation of chromosomes during meiosis can provide information about the likelihood of aneuploidy or other genetic abnormalities in gametes.

These diagnostic approaches can be used to identify genetic disorders, chromosomal abnormalities, and other genetic variations that may be associated with a patient's symptoms or medical history. They can help to guide treatment decisions and provide information about the risk of passing on genetic conditions to offspring.

Application of artificial intelligence in mitosis and meiosis process

Artificial intelligence (AI) has been applied in various ways to the study of mitosis and meiosis. Some examples of its application include:

- Gamete and Embryo Selection: AI technology has been used to assess and select sperm, oocytes, and embryos, aiding in the success of Assisted Reproductive Technology (ART). AI can analyze large amounts of data, especially video and images, to provide more objective gamete and embryo selection, thus improving the success rate of ART procedures

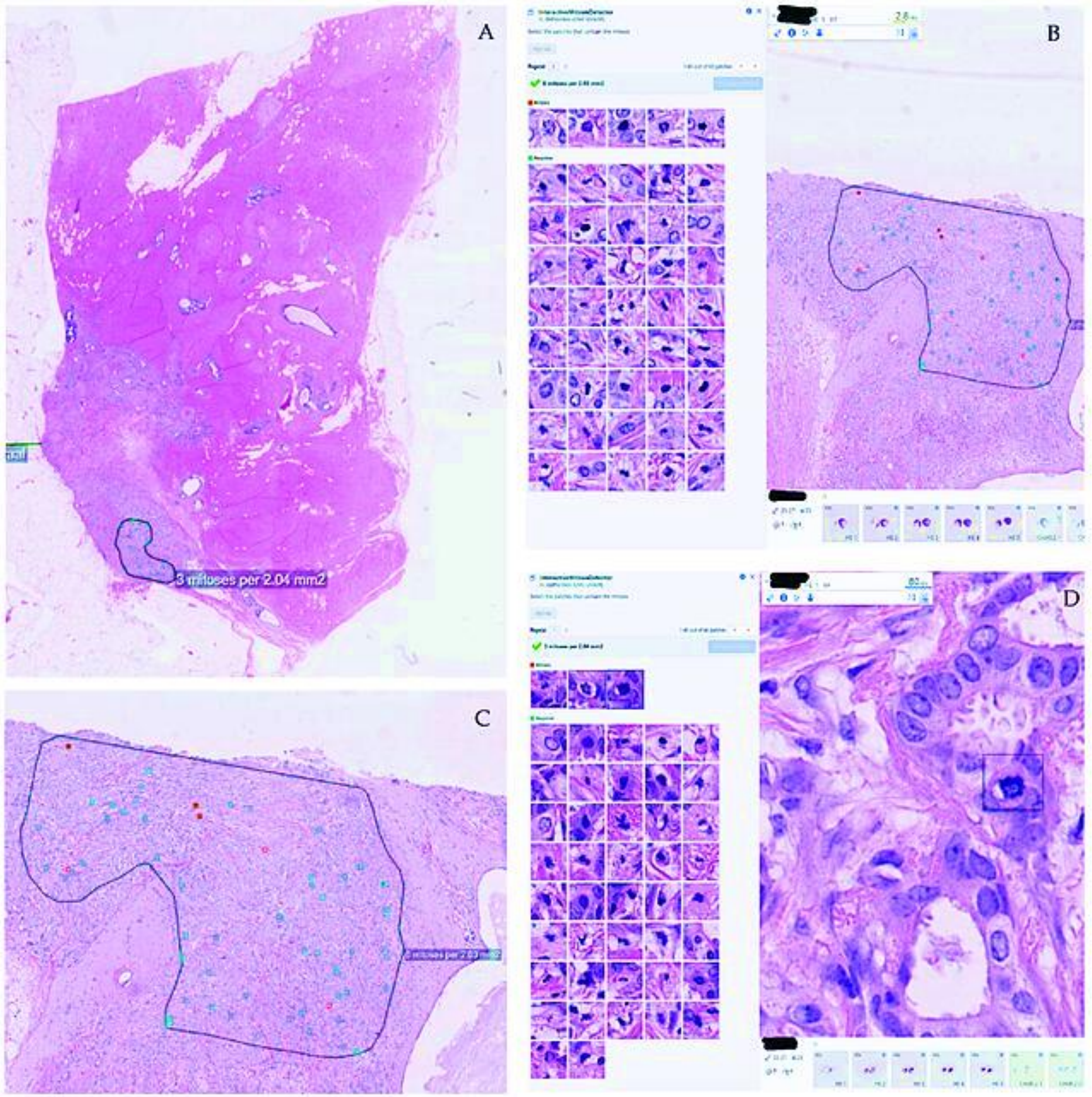


https://miro.medium.com/v2/resize:fit:1400/0*IDPVwRi8cldaNnhG.png

The researchers trained the deep learning system (sub branch of machine learning) using images of embryos captured at 113 hours post-insemination. Among 742 embryos, the AI system was 90% accurate in choosing the most high-quality embryos.

Application of artificial intelligence in mitosis and meiosis process

- Mitotic Cell Identification: Researchers have developed deep-learning models for AI to recognize mitotic cells in microscopy images, streamlining the process of identifying and analyzing mitosis. This technology can be particularly beneficial for tracking the pathway of mitosis in plant species and automating the analysis of a large number of images

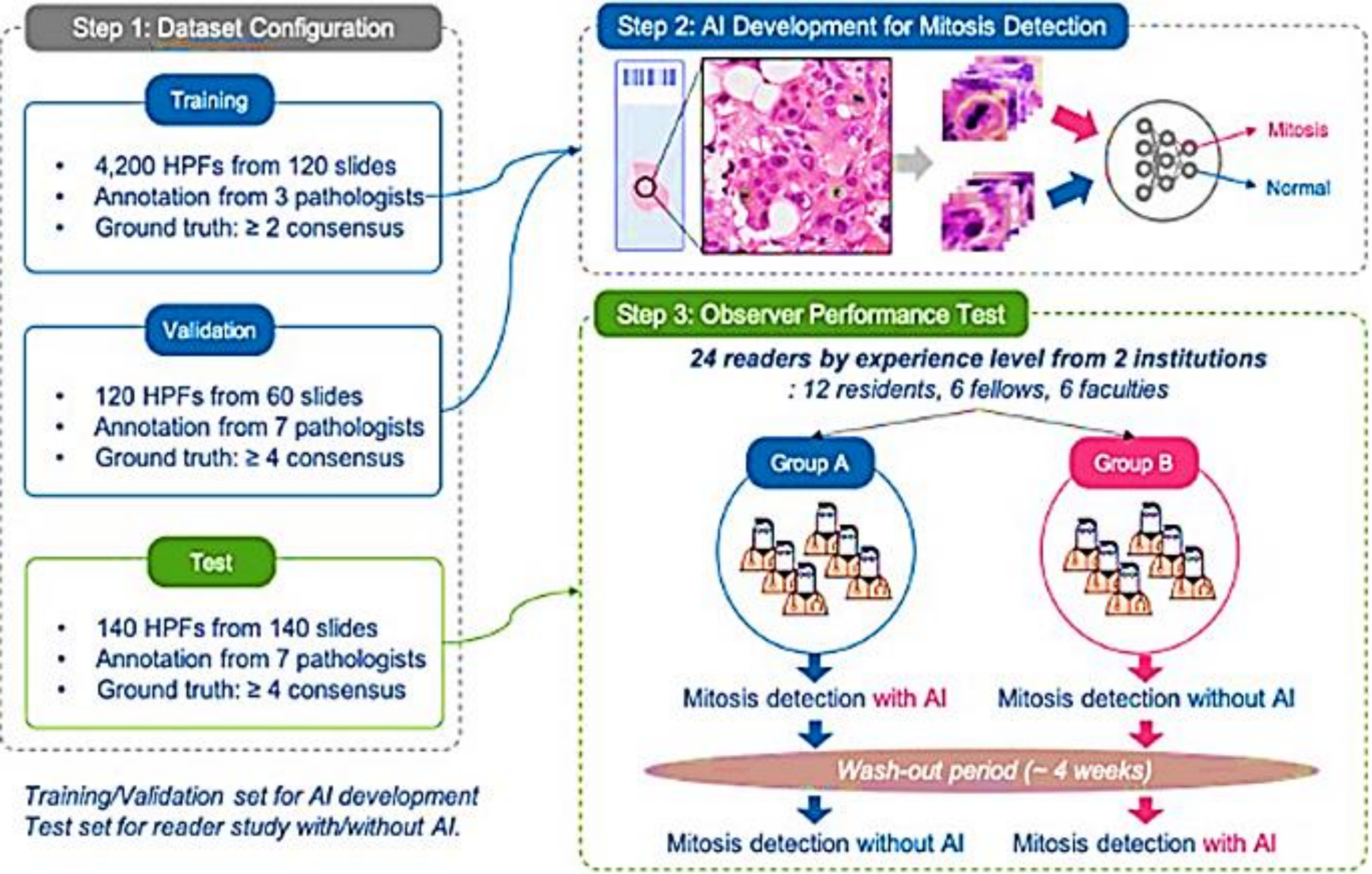


In-house developed AI algorithm for mitotic figures recognition. (A) Selecting a region of interest. (B) and (C) Interactive Mitosis Detector, with gallery (B) and without gallery (C). The detector highlights those areas suspicious for mitosis with orange, those negative for mitosis as green. (D) Close-up of mitotic figure (mitotic figure selected by the pointer on the right in the gallery), recognized by the algorithm.

https://www.researchgate.net/publication/360152558/figure/fig1/AS:1160604412854272@1653721063418/In-house-developed-AI-algorithm-for-mitotic-figures-recognition-A-Selecting-a-region.png

Application of artificial intelligence in mitosis and meiosis process

- Mitosis Analysis: Artificial intelligence methods, such as convolutional neural networks (CNN), have been used for mitosis detection in digital pathology workflow and AI solutions. These AI algorithms can aid in the accurate and clinically usable analysis of mitotic cells in various types of cancer and tissue samples.



Flow chart of the methodology and datasets employed in developing and validating an AI-based tool to quantify mitoses in breast carcinoma

Pantanowitz, L., Hartman, D., Qi, Y. et al. Accuracy and efficiency of an artificial intelligence tool when counting breast mitoses. Diagn Pathol 15, 80 (2020). https://doi.org/10.1186/s13000-020-00995-z

Application of artificial intelligence in mitosis and meiosis process

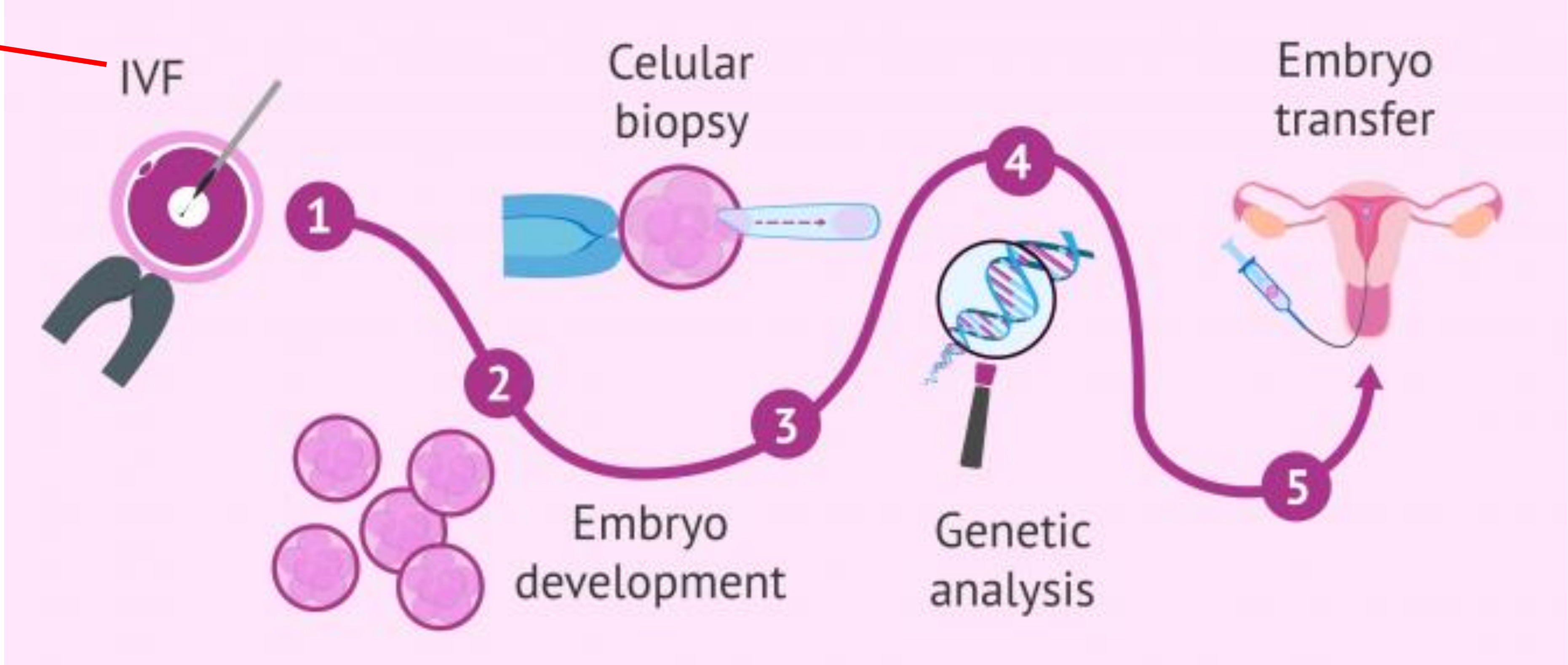
- Genetic Diagnosis and Impact of Meiosis: AI has been involved in the genetic diagnosis of subfertility, particularly in understanding the impact of meiosis and maternal effects. Meiotic gene-specific panels and AI technology are used to uncover the contribution of single genes to meiotic errors, thus improving the understanding of the meiotic process and its impact on fertility.

Application of artificial intelligence in mitosis and meiosis processes

- Preimplantation Genetic Diagnosis (PGD): AI has enabled direct testing of the outcome of the first and second meiotic divisions, providing valuable insights into meiotic and mitotic errors. This has practical relevance in preimplantation genetic diagnosis for poor prognosis IVF patients, contributing to the understanding of meiotic and mitotic nondisjunction.

These applications demonstrate the diverse ways in which AI is being used to study and understand the processes of mitosis and meiosis, ranging from gamete and embryo selection to the genetic diagnosis of subfertility and the analysis of mitotic cells in various medical contexts.

IVF: In Vitro Fertilization



Genetic analysis: study of the chromosomes and/or genes in the biopsied cells to identify possible alterations in them. Specifically, chromosome analysis is better known as preimplantation genetic screening and, on the other hand, the term PGD is used for the analysis of specific genetic mutations.

https://www.invitra.com/en/about-the-pgd-process/

Useful References

- Study.com. Mitosis Lesson Plan.
- Study Mind. Meiosis - Mitosis and Meiosis (GCSE Biology).
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- YouTube. Mitosis and Meiosis with Diagram II How cell is Divide II Chapter 3 Class 8 Science Oxford Syllabus.
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THANK YOU!